Research review
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The field of of AI planning is focused on developing intelligent strategies to navigate complex state-space environments.The following review is intended to highlight significant research in AI planning as it pertains to the high-level topics:

(1) Representation: the abstractions used to represent relevant components of the state-space environment
(2) Planning: the techniques used to optimize decisions within the abstracted state-space environment
(3) Heuristics: rules that can be used to inform the efficiency and accuracy of planning

Representation
Representation languages provide researchers with the means to formalize a state-space environment into terms that can be evaluated through some process of strategic planning. As a general requirement, these languages must be sufficient to capture information about the environment that is necessary to perform intelligent actions, but not unduly complex so as to avoid an unnecessary burden on computation time. One of the most seminal representation languages in the development of AI planning is the **The Stanford Research Institute Problem Solver (STRIPS)**, as described by Fikes and Nilsson (1971, 1972). The significance of STRIPS language resides in its approach to describing environments within the framework of an initial state, a goal state that the agent is trying to reach, and a series of actions (each with conditions and preconditions) that an agents can use to move between states. Historically speaking, STRIPS is recognized as being one of the earliest representation languages of “classical planning”, that is: planning that is conducted on a fully observable, deterministic search space. Several elaborations have been applied to improve the applicability STRIPS, for example, providing for the consideration of negative literals (see the **Planning Domain Definition Language**, McDermott et. al., 1998). Though partially incomplete, STRIPS(based) languages still form the basis of many highly effective forms of automated planning algorithms, as discussed with Graphplan below (Blum & Furst, 1997)

Planning
Planning is a process whereby state-space elements (as defined by a representation language) are evaluated and optimized according to their ability to achieve the goal state. Progression state-space search is a method that evaluates paths sequentially, starting with the initial state and moving towards the goal. Conversely, regression state-search starts from the goal state, and evaluates paths backwards towards the initial state. Regressive search has the advantage of only evaluating paths that are known to reach the goal state; however, as stated by Russell & Norvig (2010), neither progression or regression based methods are uniformly ideal in terms of arriving at an efficient solution. An important elaboration on search planning was demonstrated with the development of **partial-order planning**. Partial-order planning models allow for actions to be considered out of order (as opposed to sequentially forward or backwards). and impose a specific sequence only when required. The effectiveness of partial order planning was demonstrated by the NOAH planner (Sacerdoti, 1975), where a planning representation called a “procedural net” was used to execute non-sequential series of actions to achieve a goal state. From a computational perspective, the significance of the partial order planning approach is particularly powerful owing to the ability to divide problems into subproblems and distribute the process of planning across multiple workers.

Heuristics
Sophisticated planning strategies can improve the efficiency with which an agent arrives at a satisfactory solution to a problem. However, even greater advantages may be realized by applying a domain-specific understanding of the search space to inform the selection paths and actions. Algorithms that are informed by

the application of domain-specific rules are called *informed heuristic search strategies*. The challenge of developing informed heuristic search strategies resides in the fact that specific rules that *could* be used to solve the problem may be unknown, and non-specific rules may be too general to be useful. One particular methodology for generating informed heuristics was realized through the development of **Graphplan** (Blum & Furst, 1997). Graphplan operates by constructing a specialized data structure known as a planning graph to express the interrelationship of states described by the planning language. The power of the planning graph resides in how the mutually exclusive options ("mutex") are incorporated within potential paths of the initial state and the goal. By recognizing different heuristics to identify these mutex relationships, the graphplan significantly reduce the search space that needs to be evaluated when considering paths to the goal state. In this sense, Graphplan is effective in its ability to generate intuitive and useful heuristics, *and* apply these heuristics to reach an efficient solution to a planning problem.

References

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